

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Constantin Bulucea and Rebecca Rossen
Assignee: Siliconix Incorporated
Title: TRENCH DMOS POWER TRANSISTOR WITH FIELD-SHAPING
PROFILE AND THREE-DIMENSIONAL GEOMETRY
Serial No.: 08/086,976 Filed: 7/2/93
Examiner: J. Carroll Group Art Unit: 2508
Attorney Docket No.: M-799-2D US

San Jose, California
March 17, 1994

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Washington, D. C. 20231

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APR 07 1994

Declaration of Constantin Bulucea

GROUP 2500

Sir:

I, Constantin Bulucea, hereby declare:

1. I am an inventor of claims 17-29 of the above-mentioned Application and inventor of the subject matter described and claimed therein (collectively, the "Subject Matter").
2. I conceived the Subject Matter prior to August 24, 1988. In support of my conception date prior to August 24, 1988, I enclose Exhibit A, which includes Figures 1-10 and 21-31A of the above-mentioned Application. Exhibit A, which shows the Subject Matter and bears the signatures of Messr. Richard K. Williams and Randolph D. Mah, are signed respectively on August 10, 1988 and August 11, 1988 in my presence.
3. Between August 11, 1988 and October 3, 1988, I worked with Mr. Lorimer K. Hill, then Patent Coordinator of Siliconix Incorporated, to obtain Siliconix's approval for an application for patent. As evidence of this effort, I enclose a letter (Exhibit B) from Mr. Hill to Mr. Paul Winters, a partner of the law firm Skjerven, Morrill, MacPherson Franklin and Friel.

LAW OFFICES OF
SKJERVEN, MORRILL,
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& FRIEL

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("Skjerven Morrill"), instructing Mr. Winters to prepare an application for patent in the United States.

3. Between October 3, 1988 and December 27, 1988, I worked diligently with my attorney Mr. John F. Schipper, who was then associated with Skjerven Morrill, to prepare a patent application. The patent application became U.S. Patent Application, serial no. 07/290,546, filed on December 27, 1988, issued on December 10, 1991 as U.S. Patent 5,072,266, from which the parent Application (serial no. 07/762,103, filed on 9/18/91) of the present Application based priority under 35 U.S.C. § 120 .

4. I did not abandon the Subject Matter at any time between my conception of the Subject Matter and December 27, 1988.

Respectfully submitted,

MAR 17 1994

Constantin Bulucea

Constantin Bulucea

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Commissioner of Patents and Trademarks, Washington, D.C., 20231, on 3/17 1994

3/17/94
Date of Signature

[Signature]
Attorney for Applicant(s)

EXHIBIT A

#6

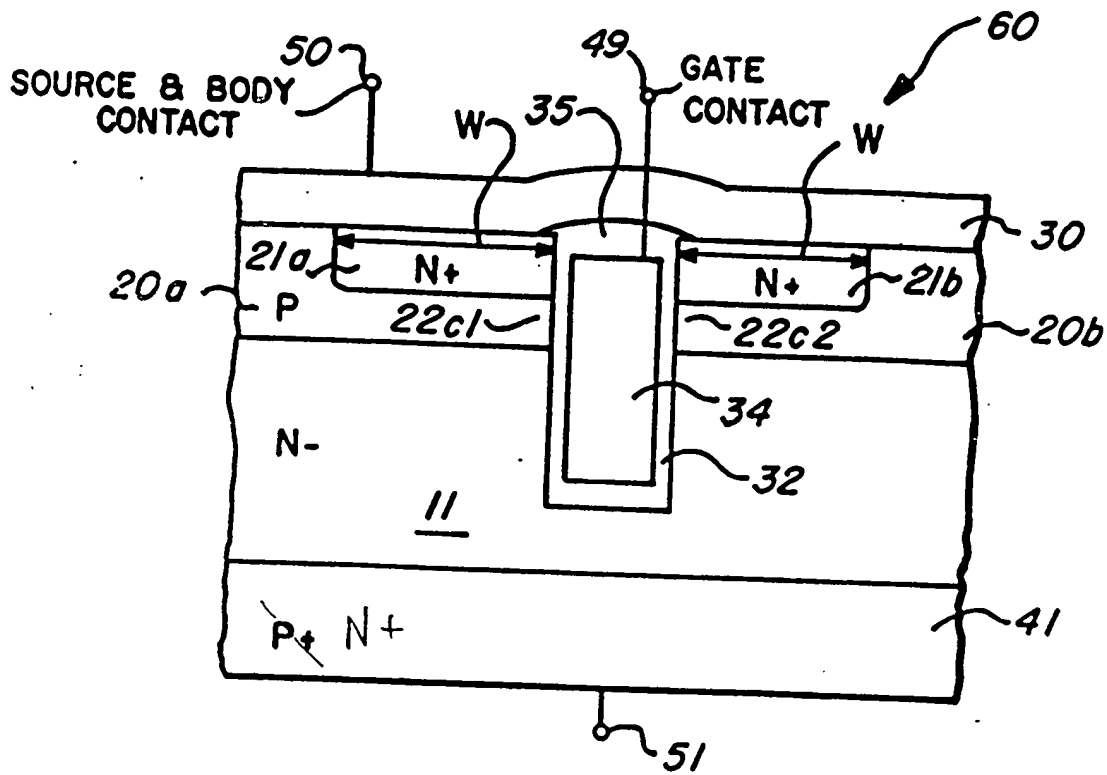


Figure 1

Cross-section of a trench DMOS power transistor cell (prior art, /1,2/).

read & understood *QW* August 10, 1988

read and understood *Randolph D. Lech* August 11, 1988

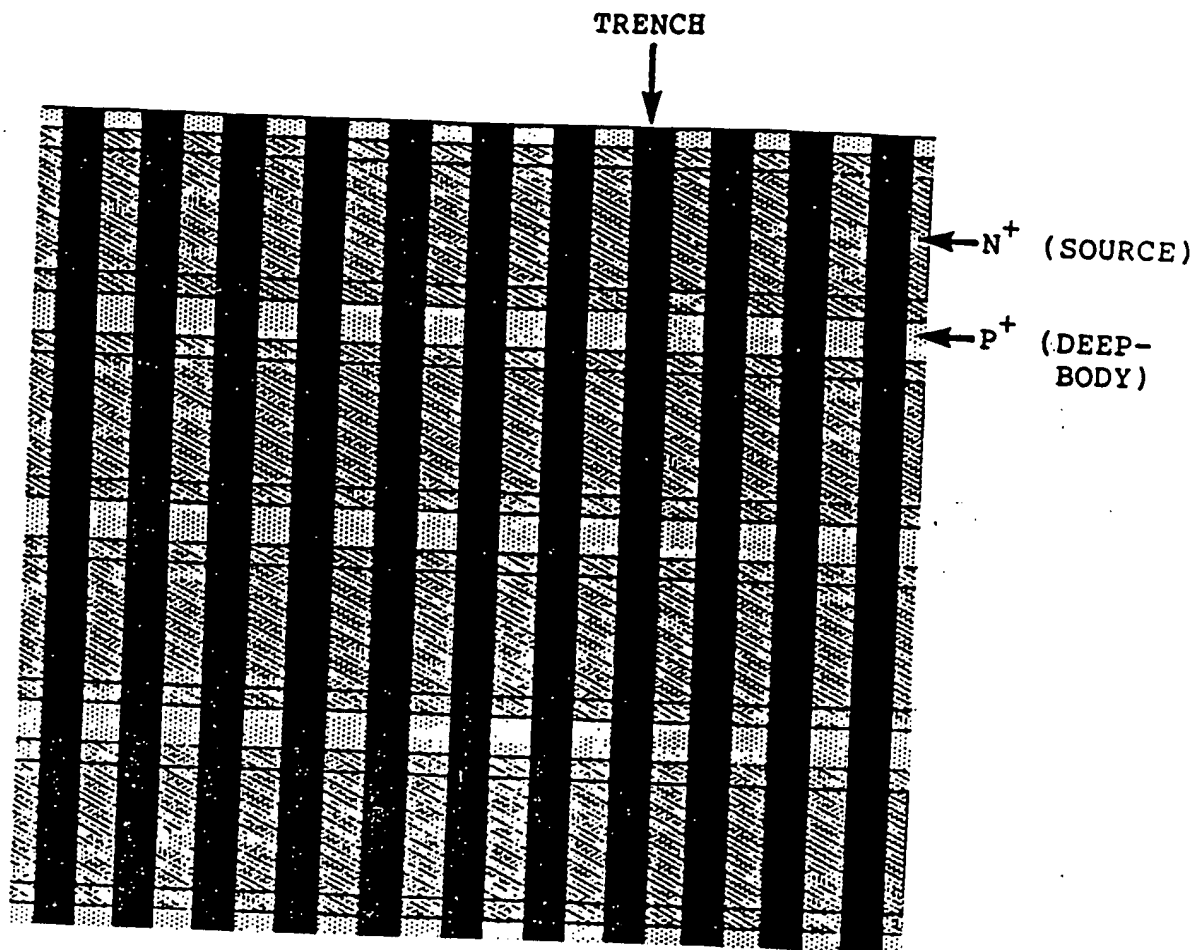


Figure 2,a

"Open-cell" implementation of a trench DMOS
power transistor (CALMA hard copy, active region).
Siliconix, Inc., 1987.

read + understood QXW August 10, 1988
read and understood Randolph D. Webb August 11, 1988

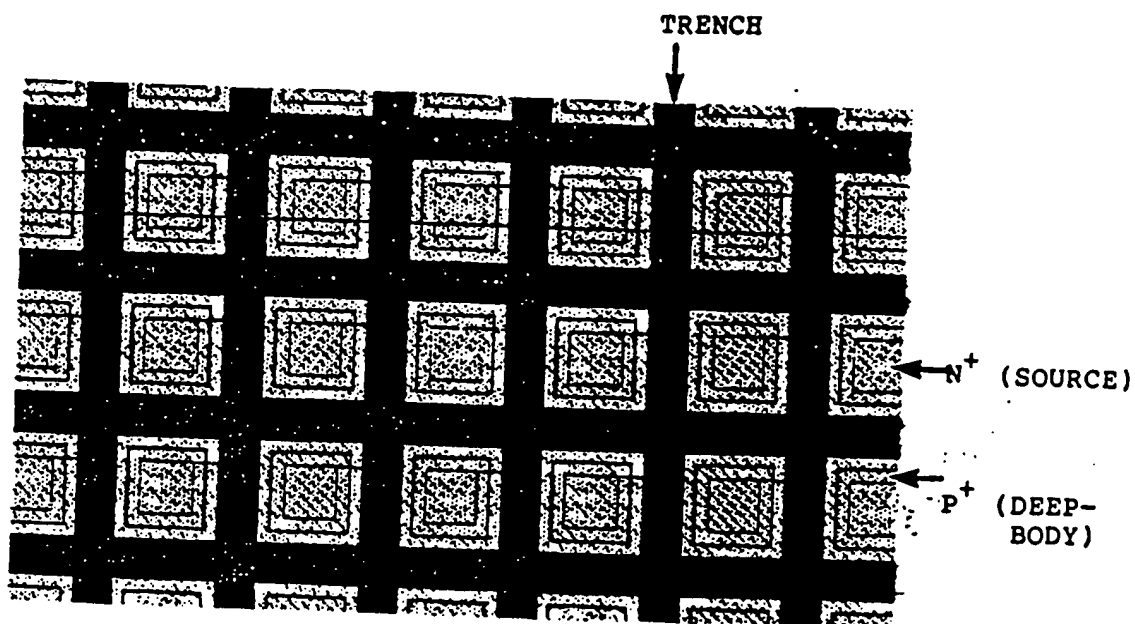


Figure 2,b

"Closed-cell" implementation of a trench DMOS power transistor (CALMA hard copy, active region).
Siliconix, Inc., 1987.

read + understood J. Q. K. W. H. August 10, 1988
read and understood Randolph D. Loh August 11, 1988

A2.4/QD5.3

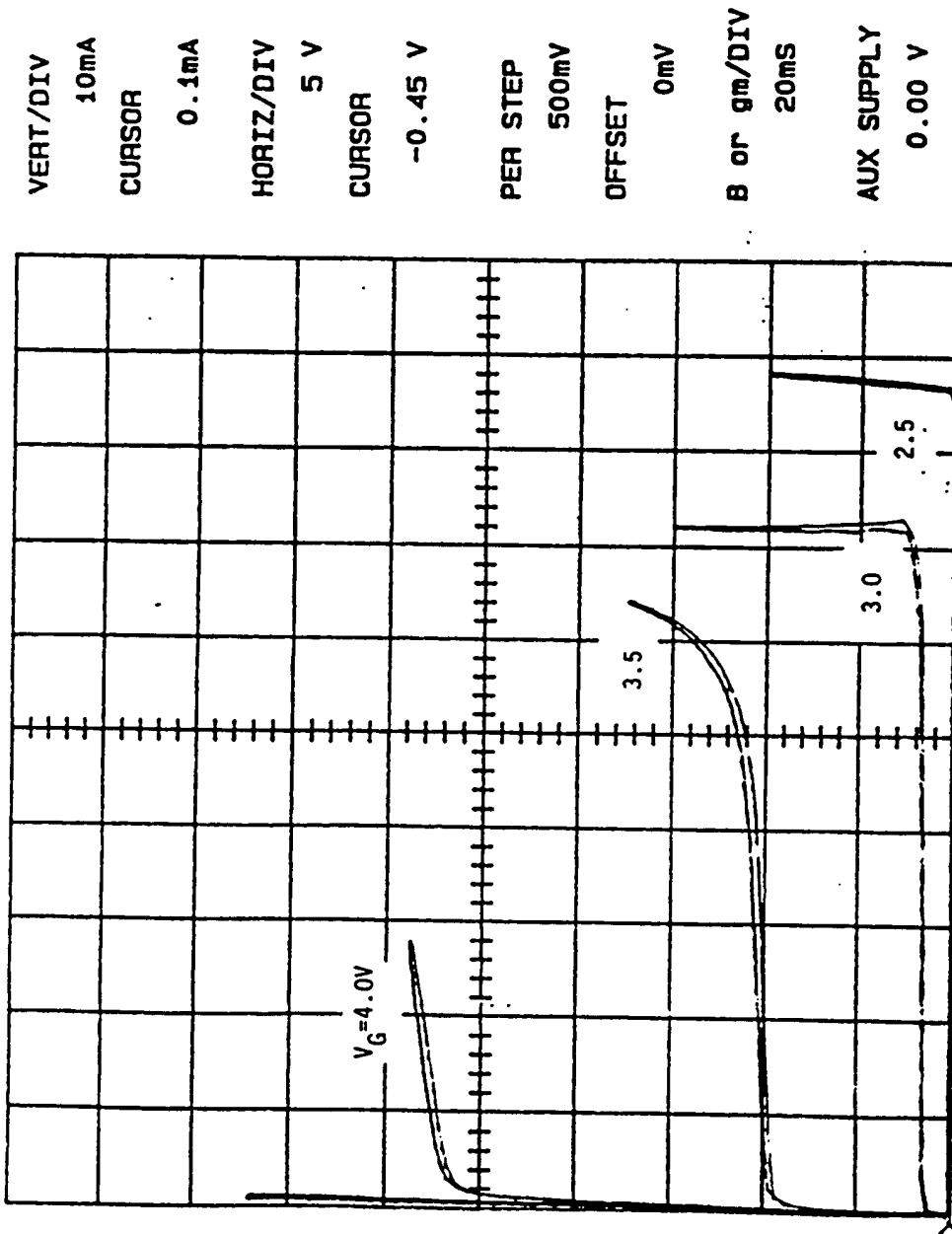


Figure 3,a

Output I-V characteristics of an experimental "open-cell" transistor having distant body contacts, perpendicular to the trenches. Siliconix, Inc., 1988.

read & understood... August 10, 1988
 read and understood August 11, 1988 Raulph D. M.

A2.1/QD5.3

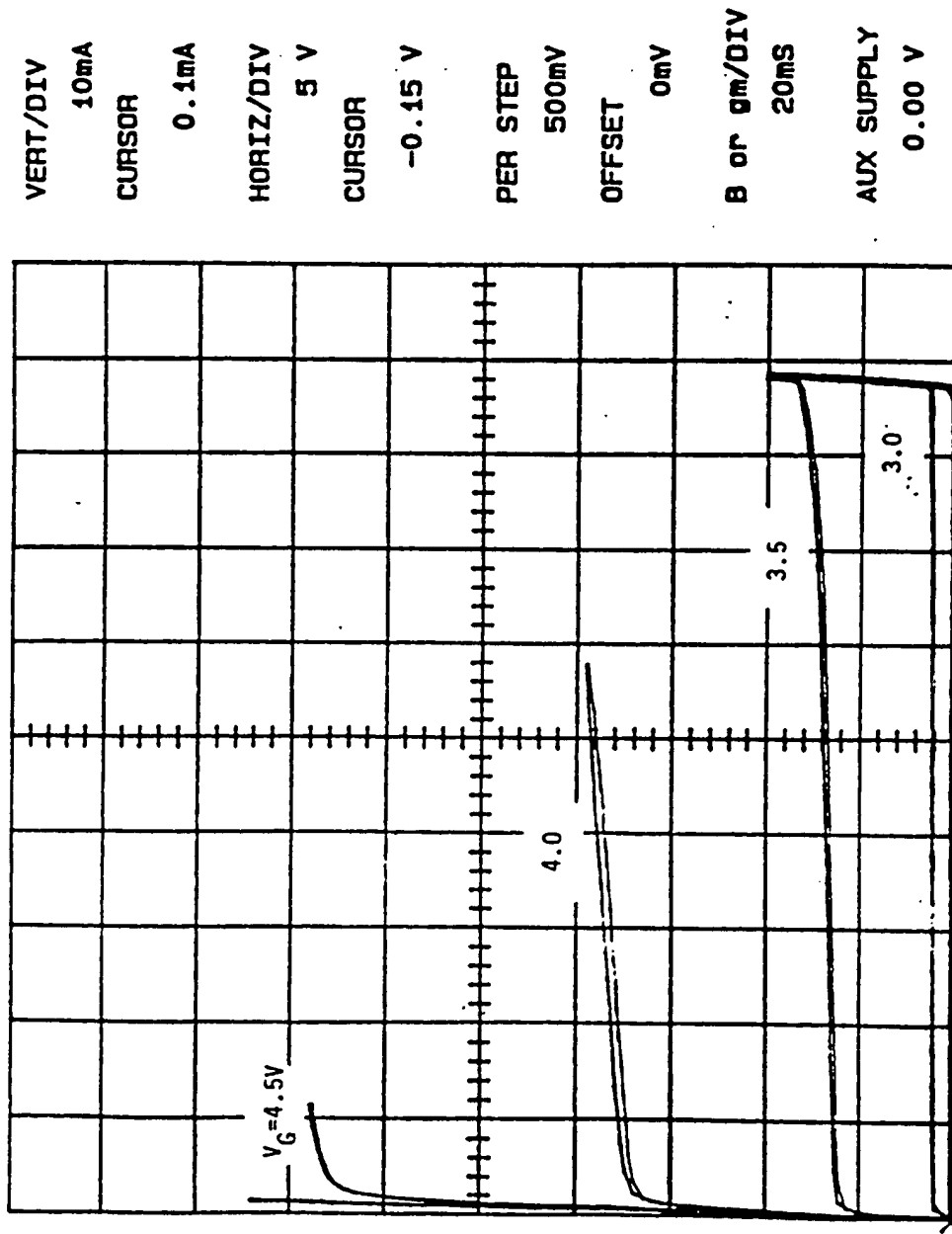


Figure 3,b

Output I-V characteristics of an experimental "open-cell" trench MOS transistor having closely-spaced body contacts, perpendicular to the trenches. Siliconix, Inc., 1988.

read & understood Q. K. W. August 10, 1988
read and understood Randolph D. Lee August 11, 1988

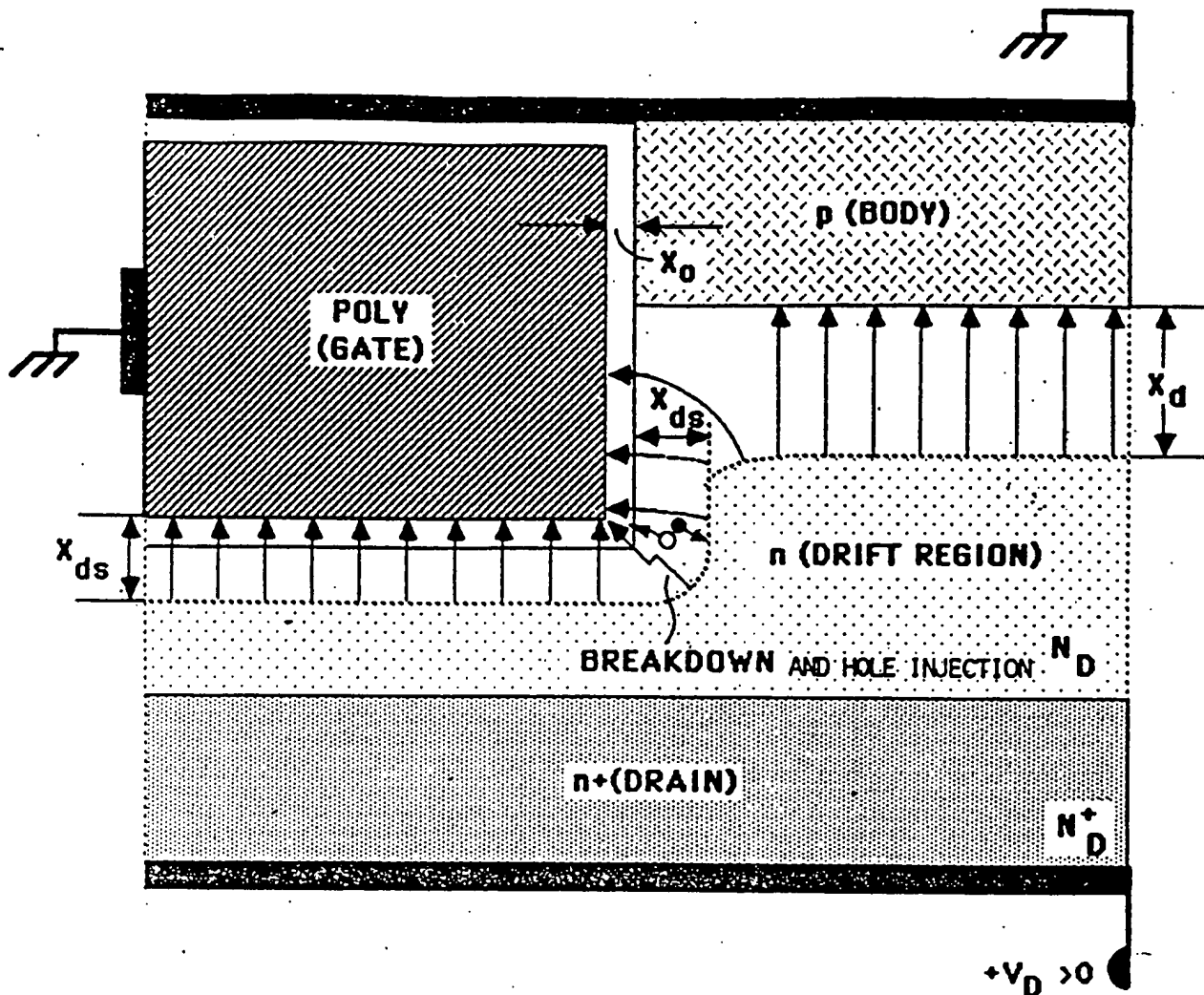


Figure 4

Qualitative description of the electric-field structure in a trench DMOS transistor having no deep-body profile provision. BVDSS biasing, source junction omitted.

read & understood Q.K.H. August 10, 1988
 read and understood Randolph D. M. August 11, 1988

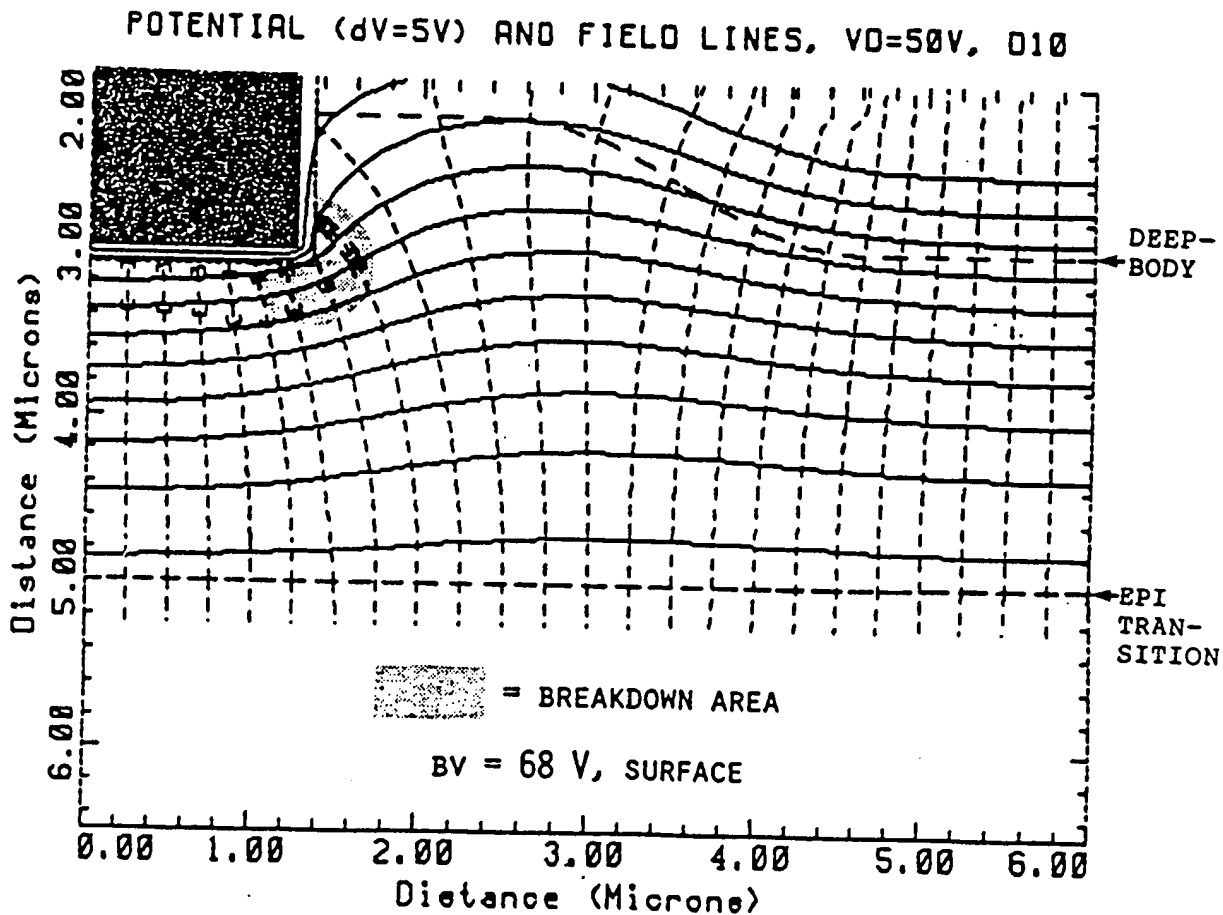


Figure 5

2-D computer simulation of the BVDSS operation of a trench DMOS transistor having the deep body junction shallower than the trench. Drain breakdown takes place beneath the trench surface.

read & understood Q-K WJA August 10, 1988
 read & understood Ruchoff D. WJA August 14, 1988

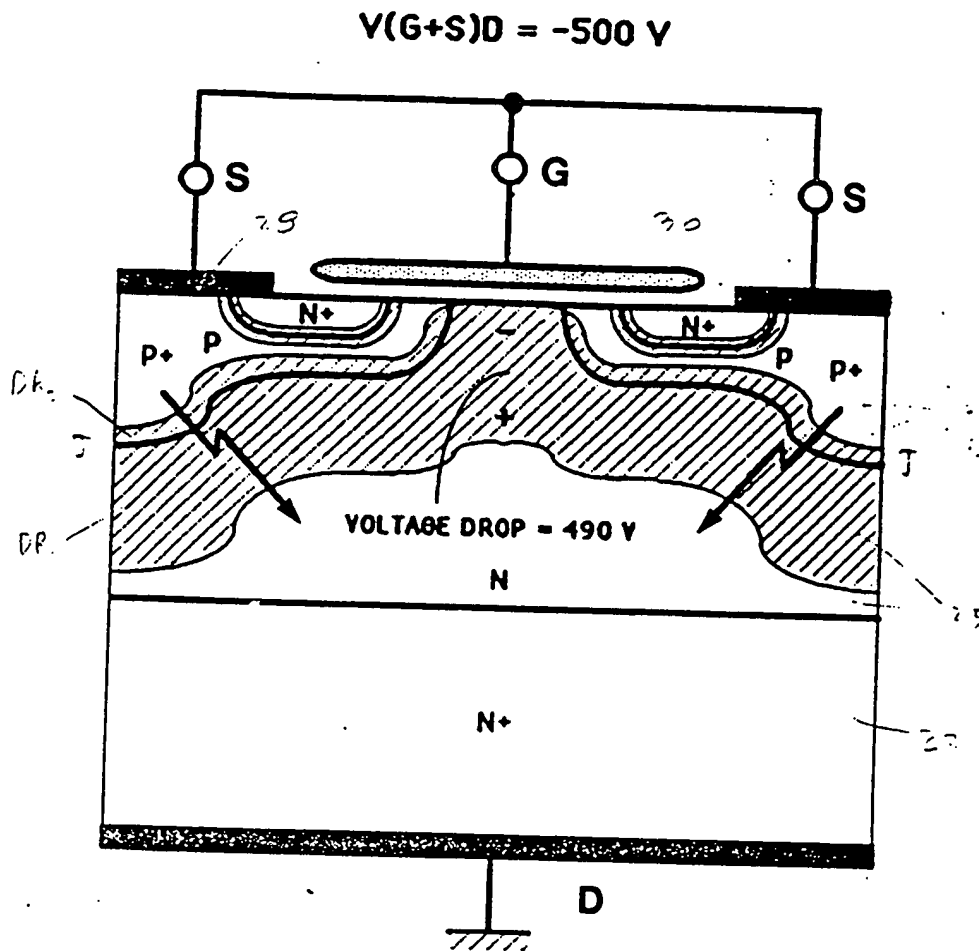


Figure 6

Junction and depletion-region topology
of a planar DMOS transistor biased in the BVDSS condition.

read + ... t... Q.K.W. Aug. 10, 1988
read at ... R. ... Aug. 14, 1988

2-D OXIDATION SQUARE-CELL DESIGN

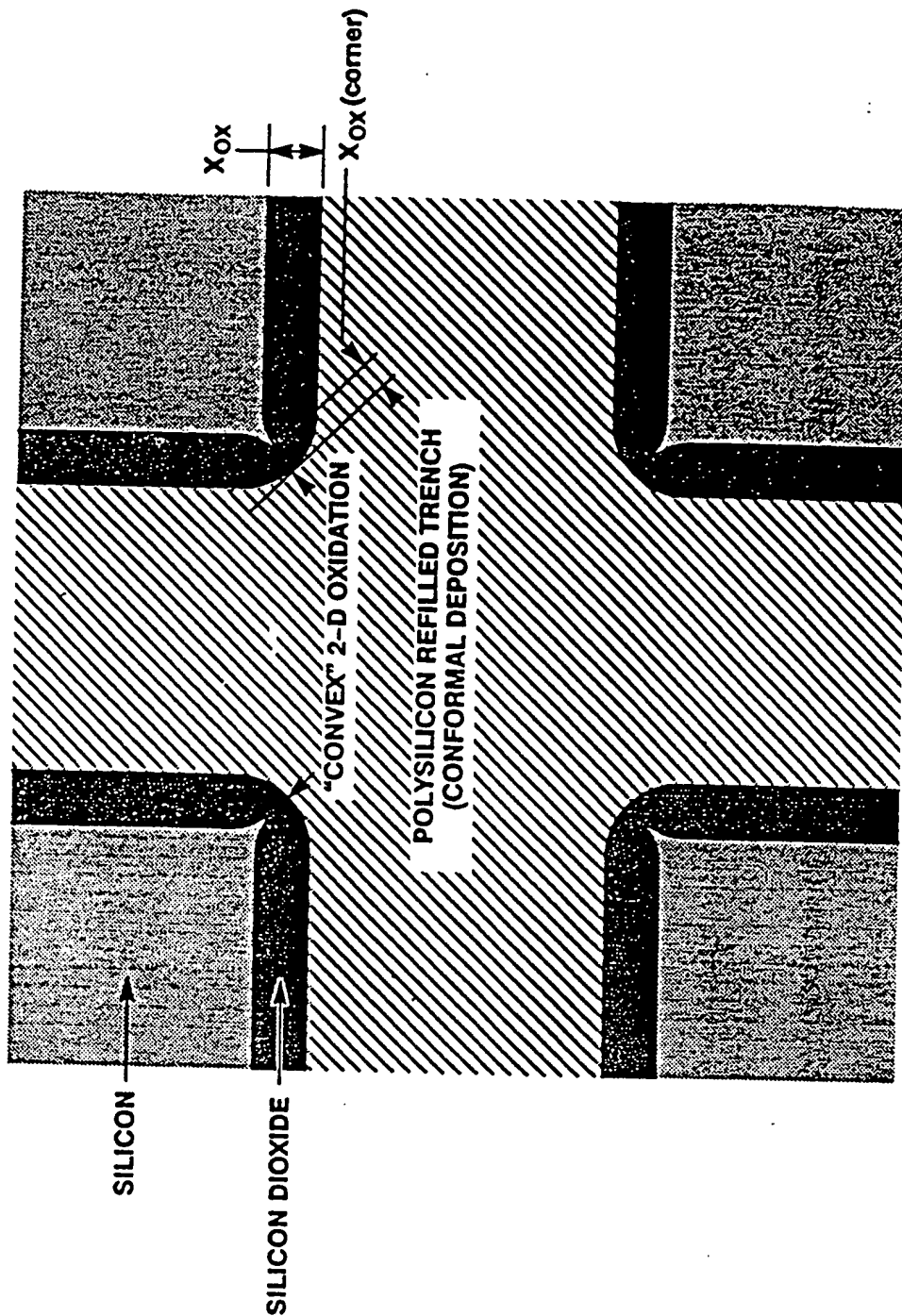


Figure 7
Qualitative description of the oxide profile
at a rectangular trench intersection.

read & understood QKWA August 10, 1988
read and understood Ralphi Dohel August 4, 1988

HEXAGONAL-CELL TDMOS

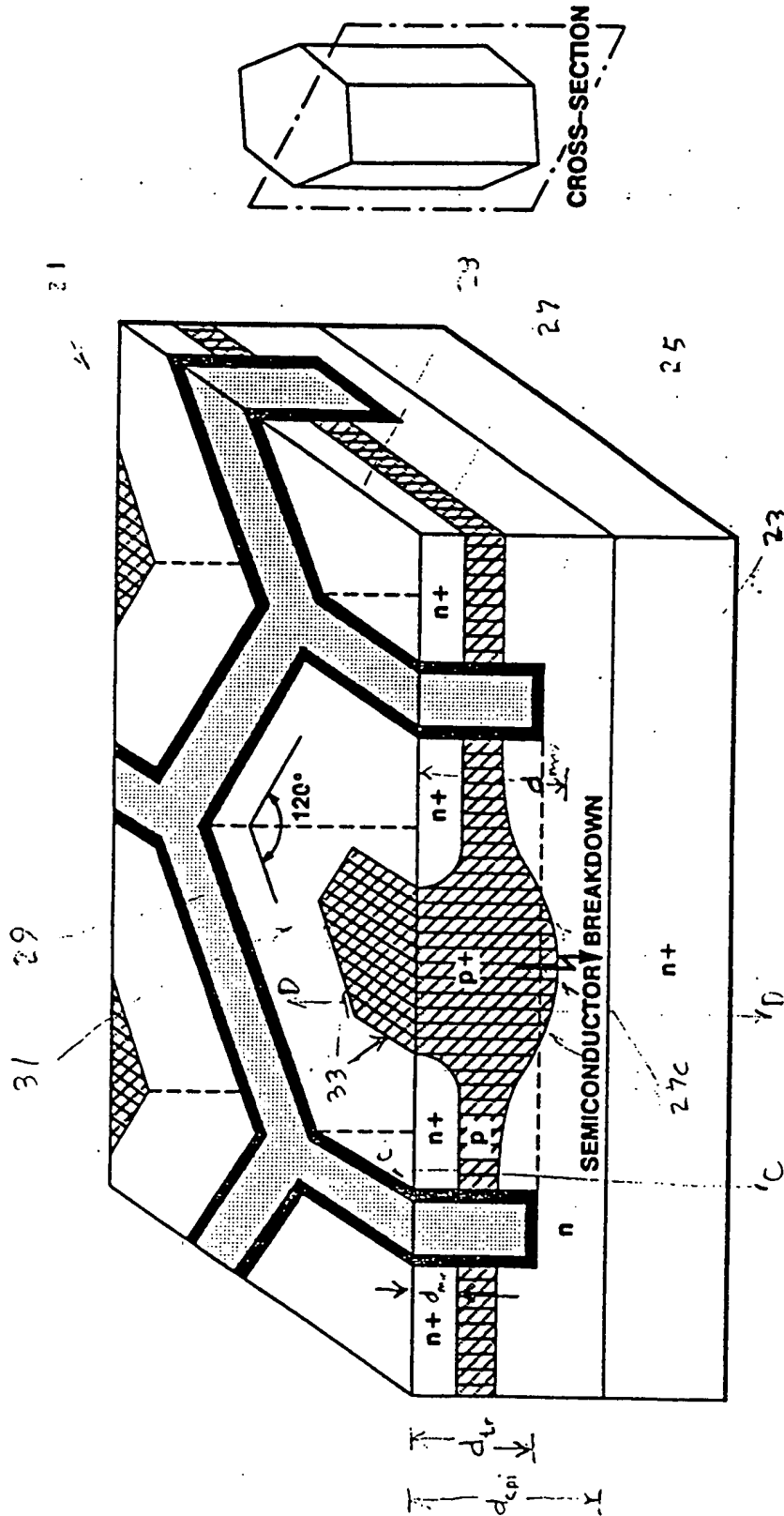
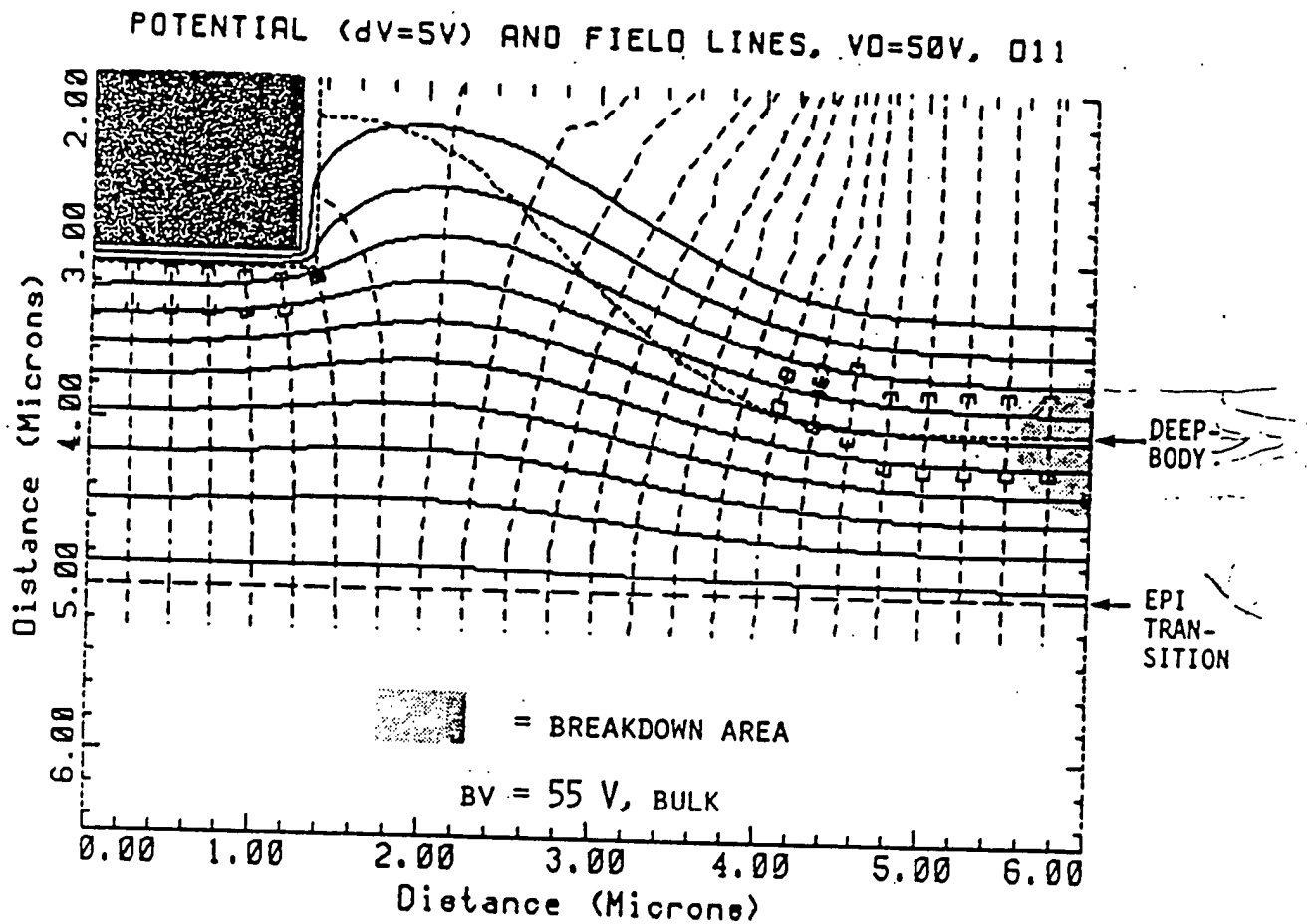


Figure 8

3-D representation of the optimized trench DMOS transistor cell proposed in this Patent Application.

read & understood by KWA August 10, 1988
read & understood by R. D. L. August 11, 1988



$$\alpha_{eff} \approx 1, \quad \alpha_{eff} = \text{strong (exp) funct. of } E$$

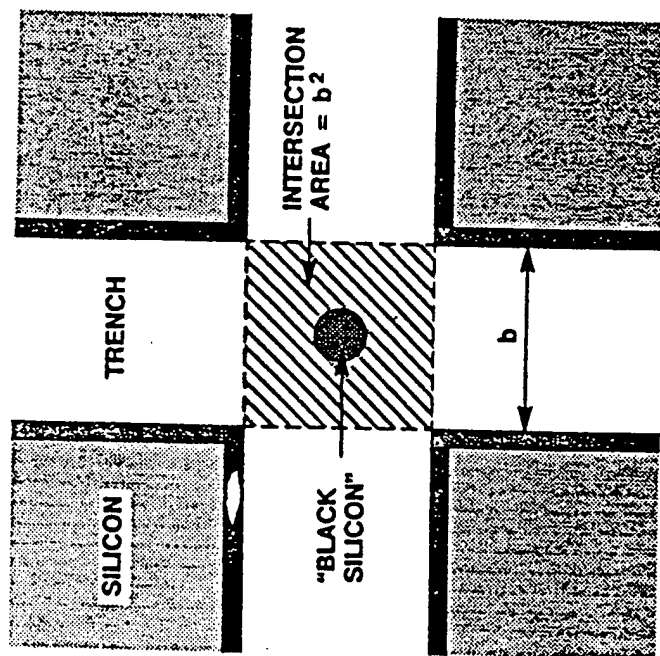
$$\alpha_{eff} = A E C^{-B/E}$$

Figure 9

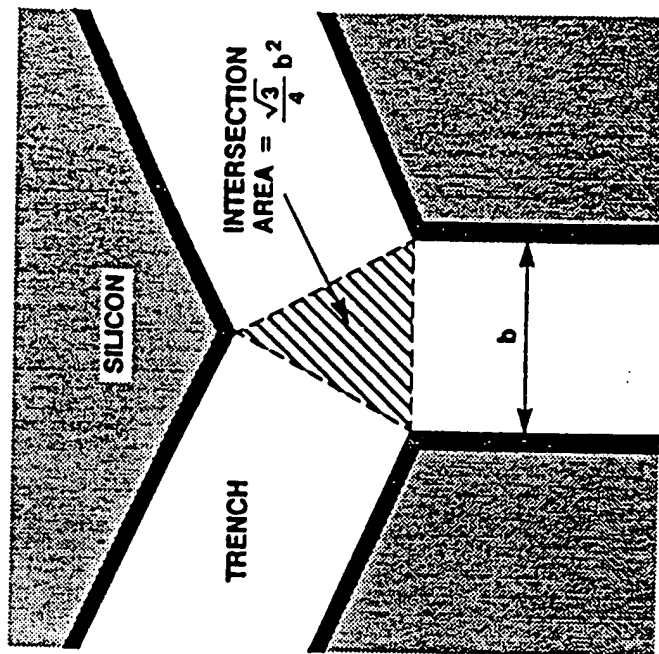
2-D computer simulation of the BVDSS operation of a trench MOS transistor having the deep body junction deeper than the trench. Drain breakdown takes place in the bulk.

revised... to... *[Signature]* August 10, 1988
 read and understood *[Signature]* August 4, 1988

"BLACK SILICON" COMPARISON



SQUARE CELLS



HEXAGONAL CELLS

Figure 10

Comparison of the "black silicon" areas at trench intersections: square cell (left) versus hexagonal cell (right).

read & understood QXW August 10, 1988
read and understood Randolph D. August 11, 1988

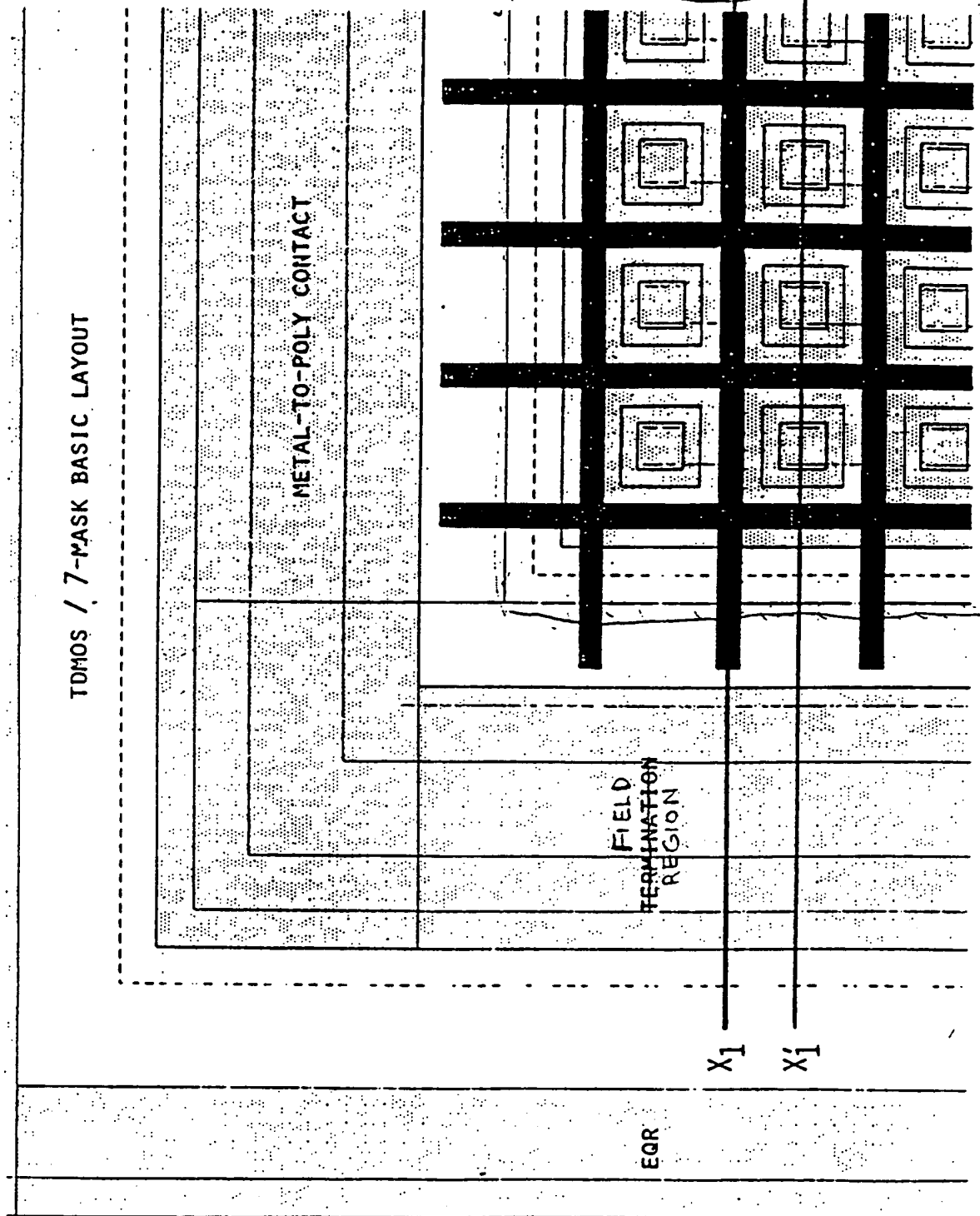


Fig. 21

read and understood QK WLL August 10, 1988
 read and understood Randolph D. WLL August 11, 1988

7-MASK TDMOS - PROCESSING BLOCK 1

n/n+ EPI → POST-EPI OXIDATION → MASK 1 = DEEP BODY → BORON IMPLANT & DIFFUSION / OXIDATION →

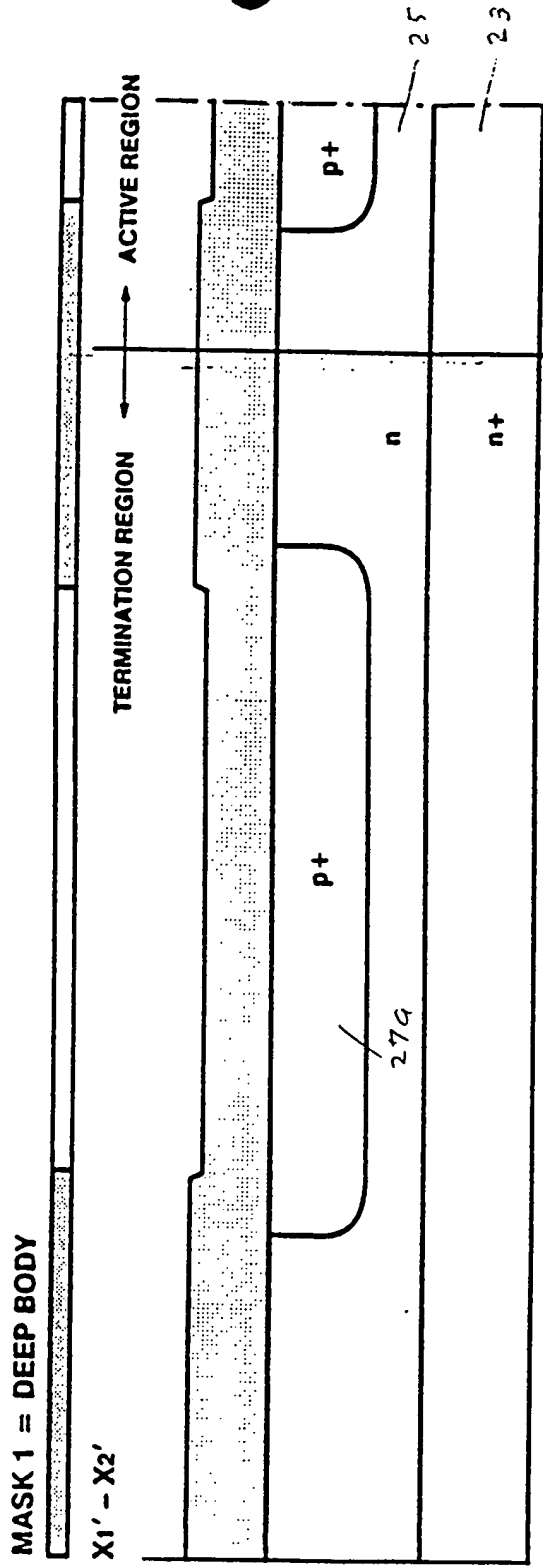


Fig. 22A

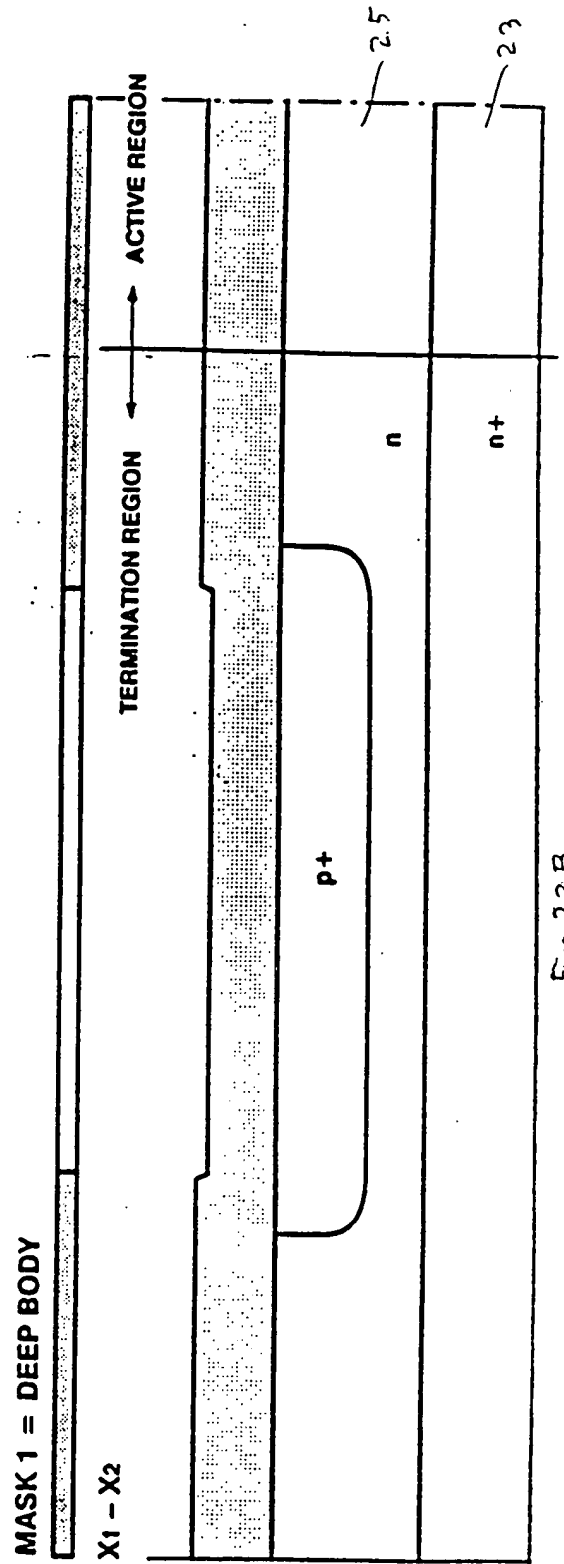


Fig. 22B

read and understood G2KWA August 10, 1988
read and understood Randolph Deleh August 4, 1988

7-MASK TDMOS — PROCESSING BLOCK 2

→ MASK 2 = ACTIVE → BORON IMPLANT & DIFFUSION / OXIDATION → ARSENIC IMPLANT & DIFFUSION / OXIDATION → LTO DEPOSITION

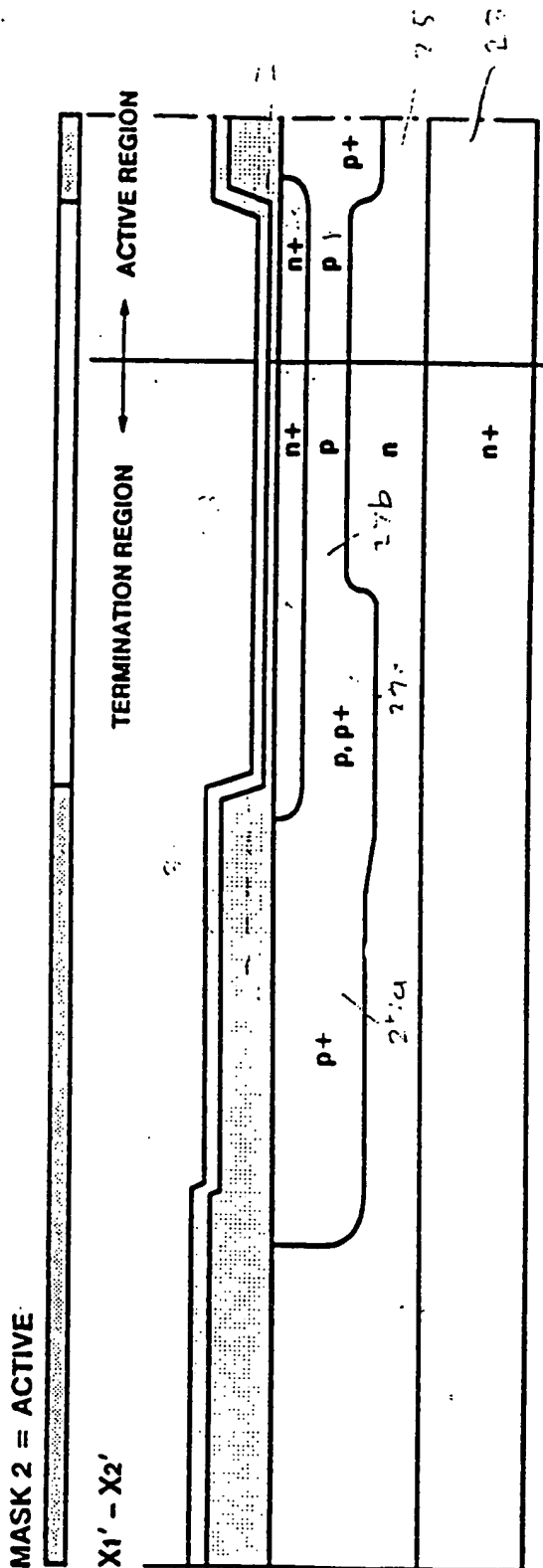


Fig. 23A

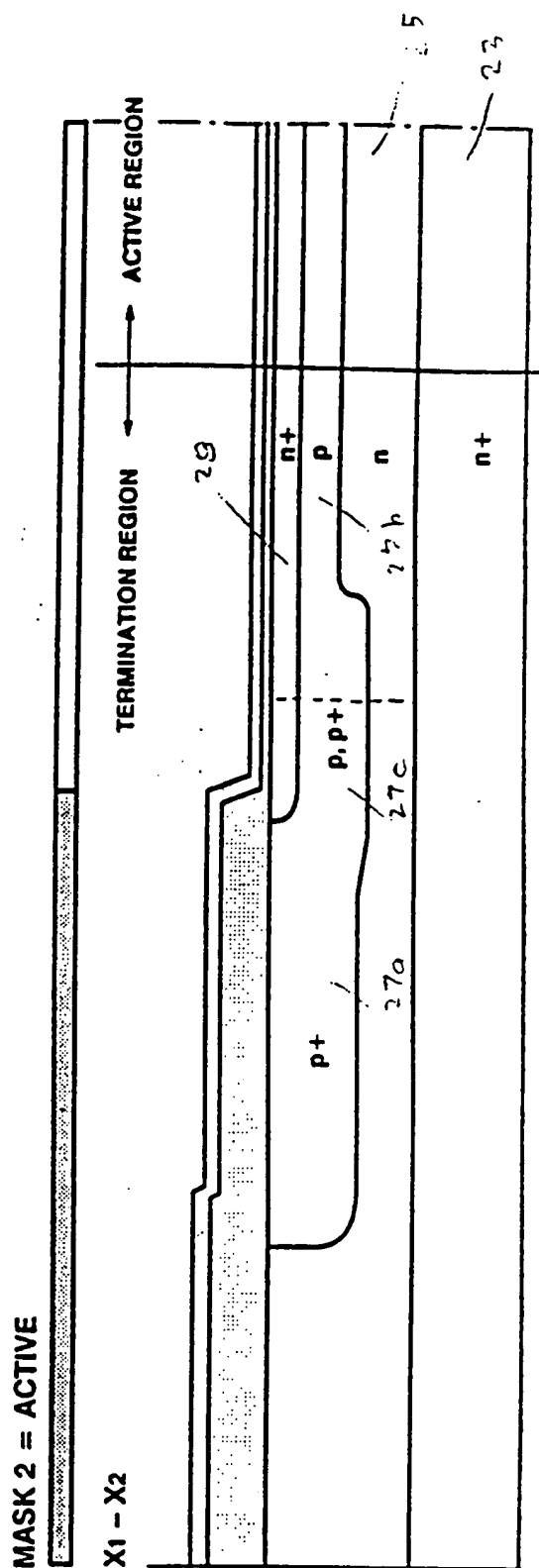


Fig. 23B

read & understood Q.K.W.H. August 10, 1988
read and understood Paul High Dole August 11, 1988

7-MASK TDMOS - PROCESSING BLOCK 3

 MASK 6 = TRENCH
  TRENCH DRY ETCHING
 

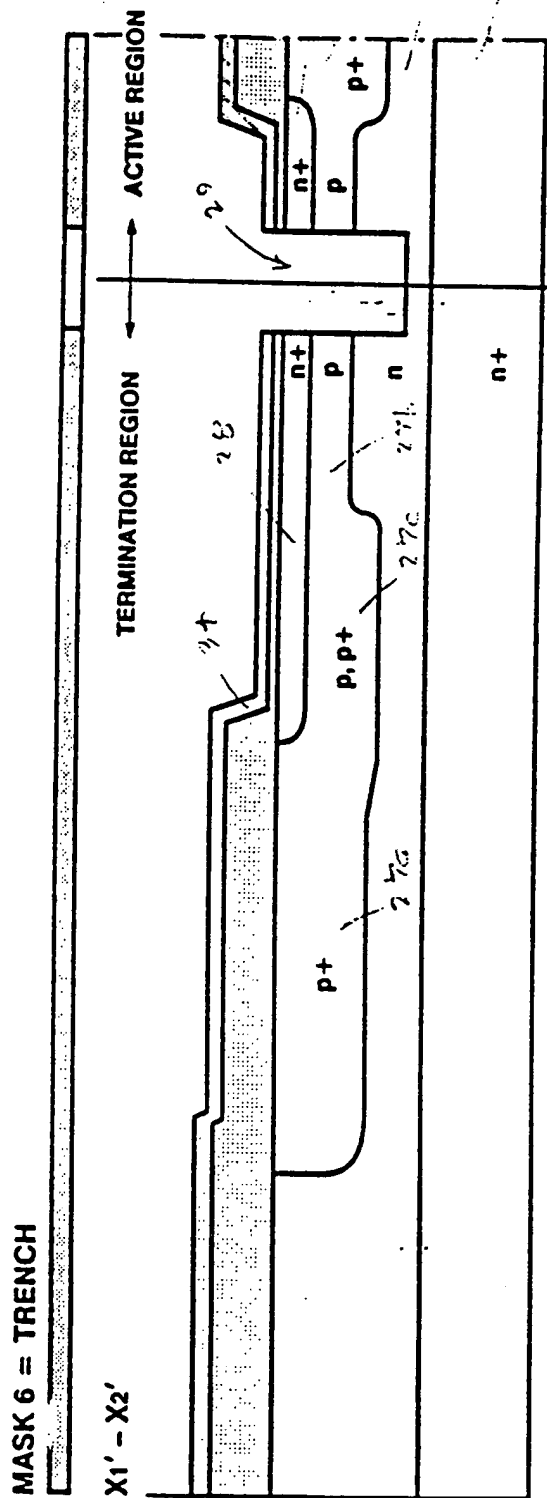
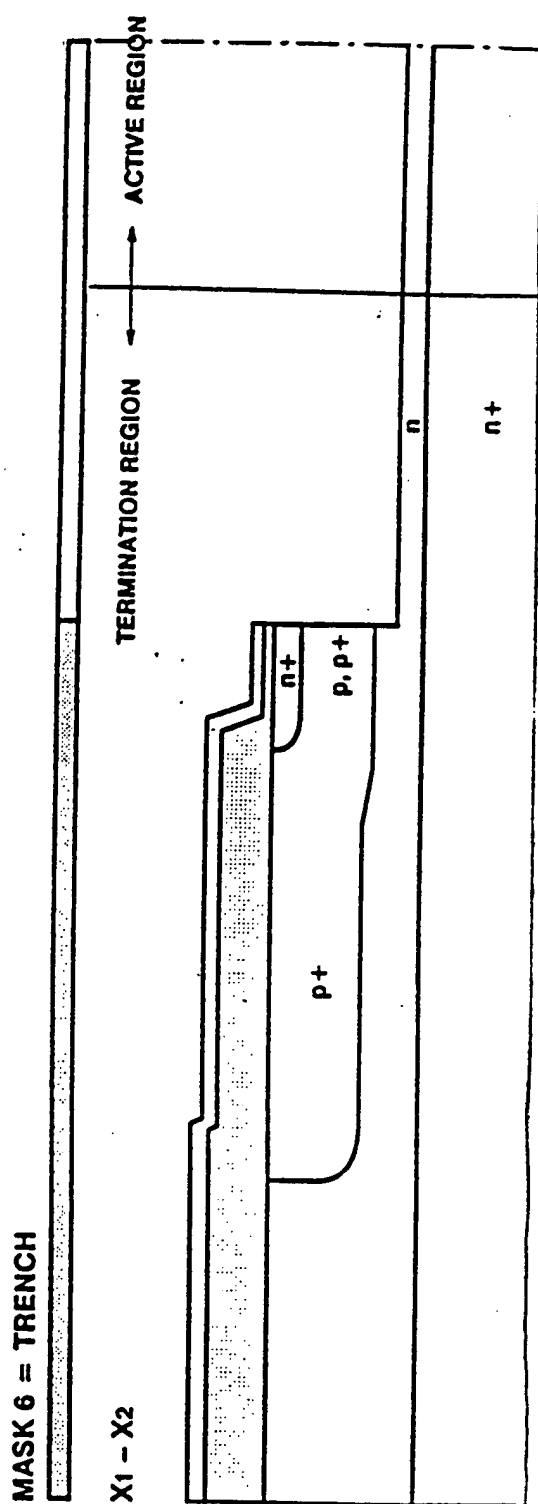
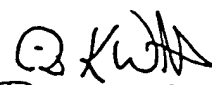


Fig. 24-A



read + understood  August 10, 1988
 read and understood Randolph D. Clark August 11, 1988

7-MASK TDMOS — PROCESSING BLOCK 4

➡ SACRIFICIAL OXIDATION & ETCHING ➡ GATE OXIDATION ➡

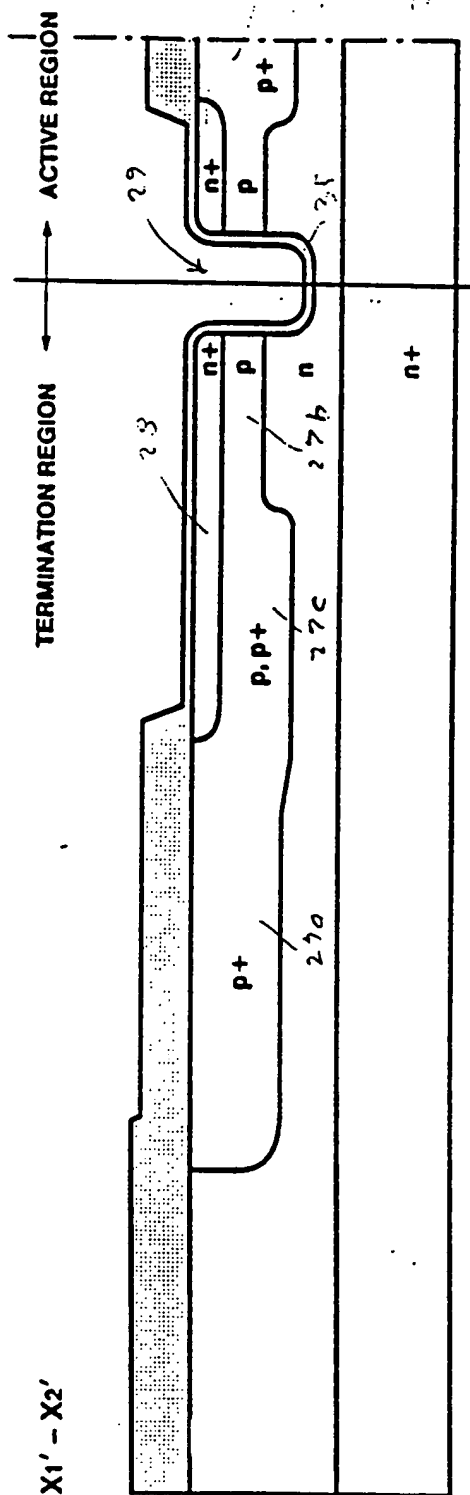


Fig. 25A

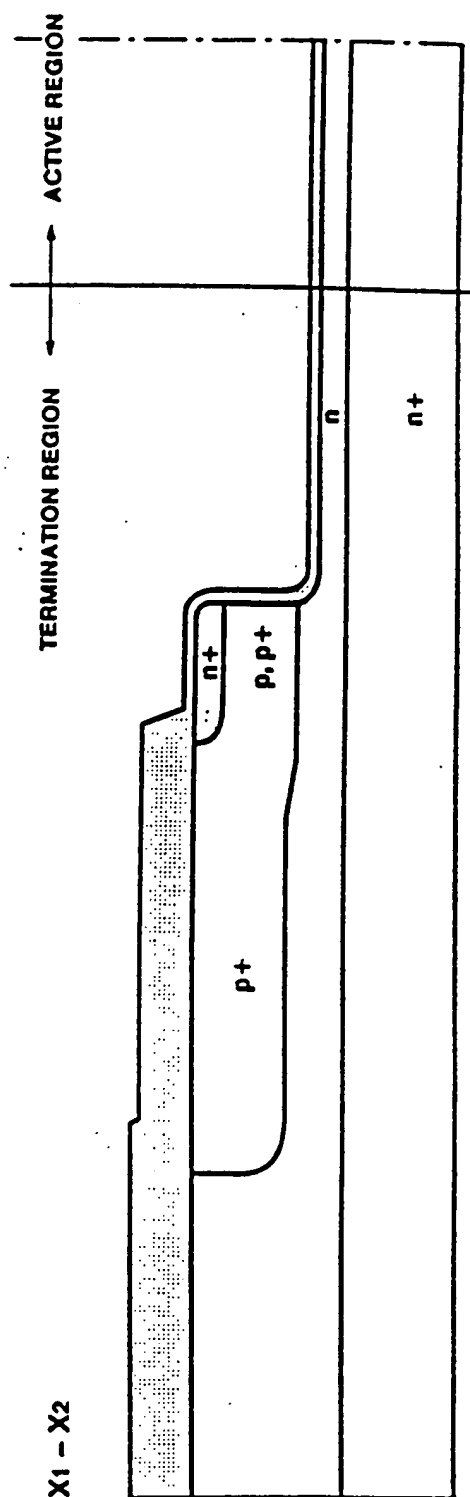


Fig. 25B

read & understood QXW August 10, 1988
read and understood Ralston August 11, 1988

7-MASK TDMOS -- PROCESSING BLOCK 5

→ FIRST POLY DEPOSITION & PHOSPHORUS DOPING → OXIDATION (ETCH STOP) →

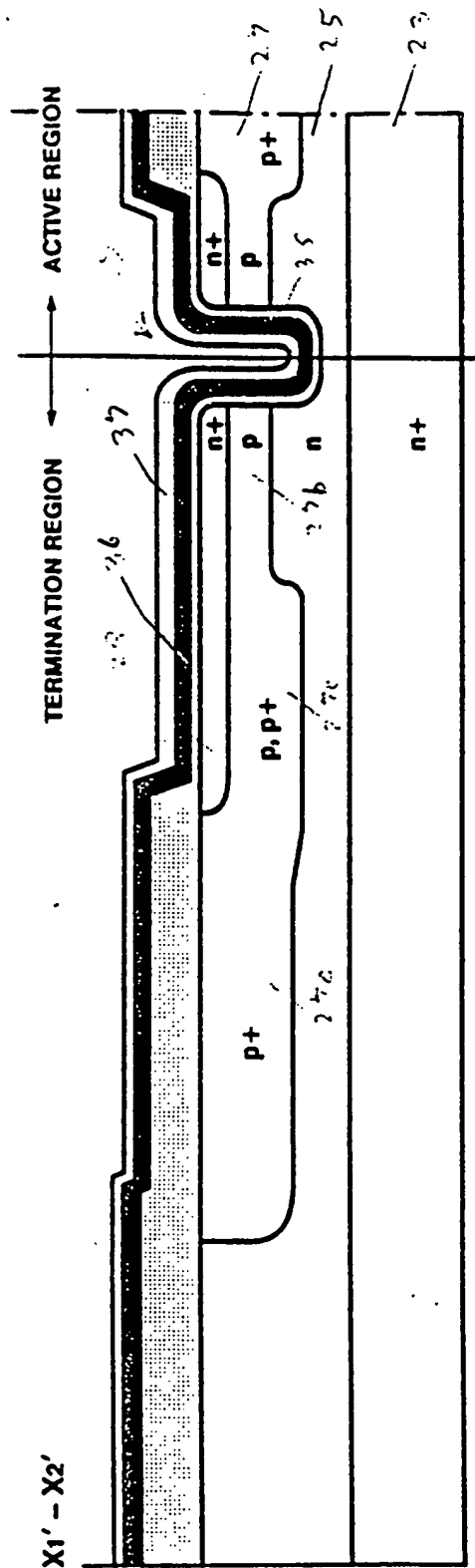


Fig. 26A

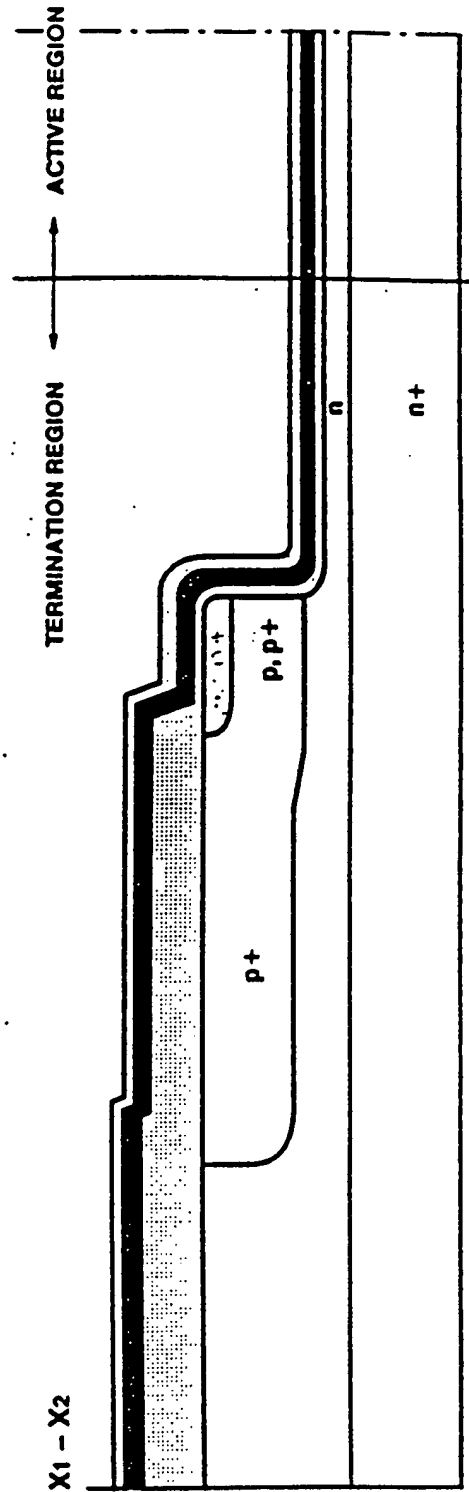


Fig. 26B

read & understood *[Signature]* August 10, 1988
read and understood *[Signature]* August 11, 1988

7-MASK TDMOS - PROCESSING BLOCK 6

→ SECOND (UNDOPED) POLY DEPOSITION →

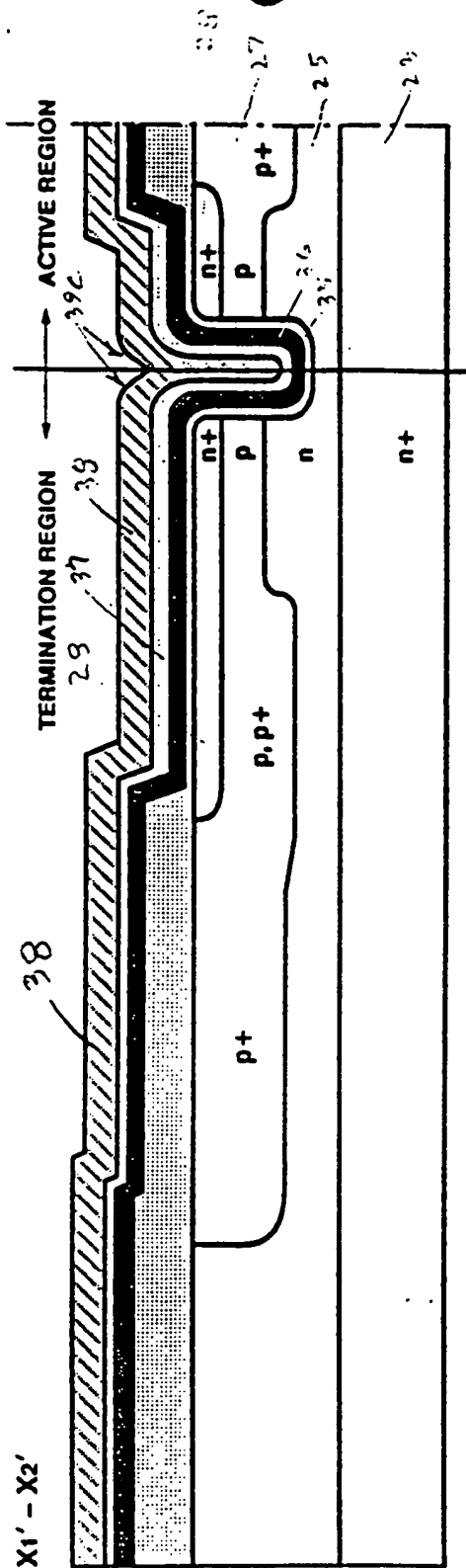


Fig. 27A

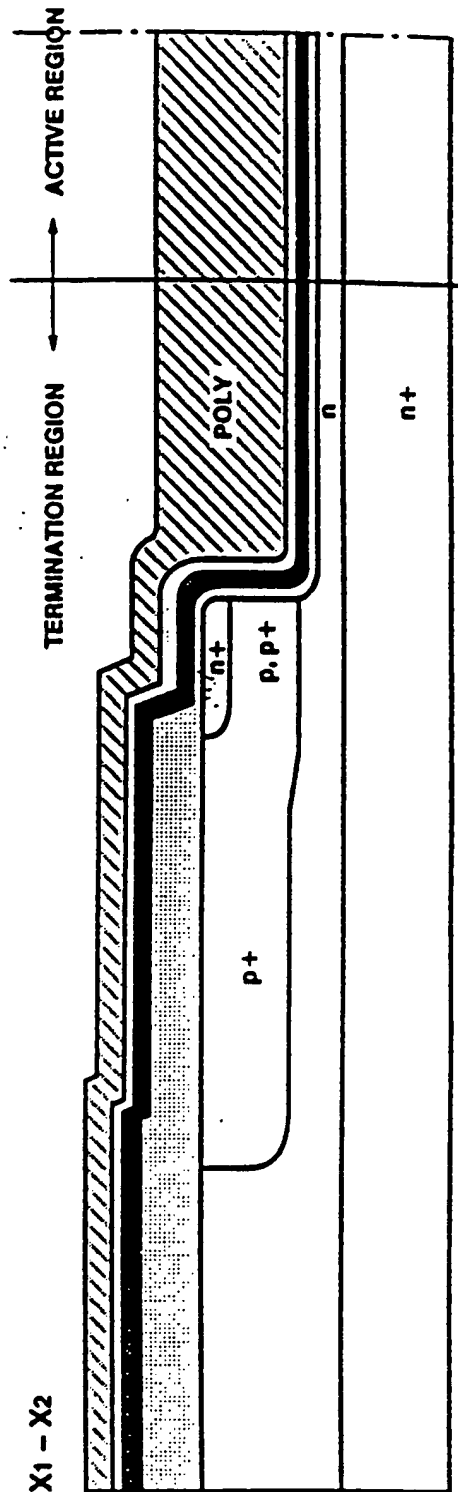
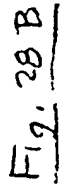
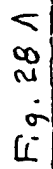


Fig. 27B

read & understood QKWH August 10, 1988
read and understood Randolph D. Lee August 11, 1988

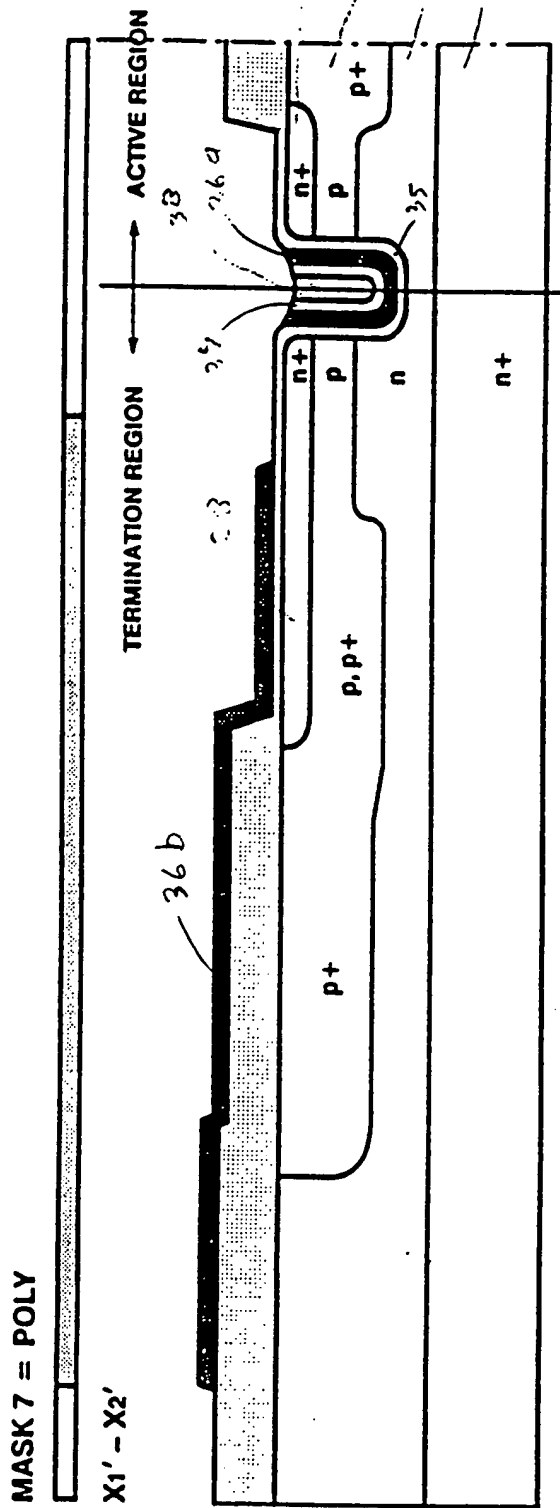
↑ POLY PLANARIZATION ETCHING → ETCH-STOP-OXIDE STRIP →



read & understood *OKW* August 10, 1988
read and understood *Paula D. Hill* August 11, 1988

7-MASK TDMOS – PROCESSING BLOCK 8

↑ MASK 7 = POLY ↑



F. 9. 29A

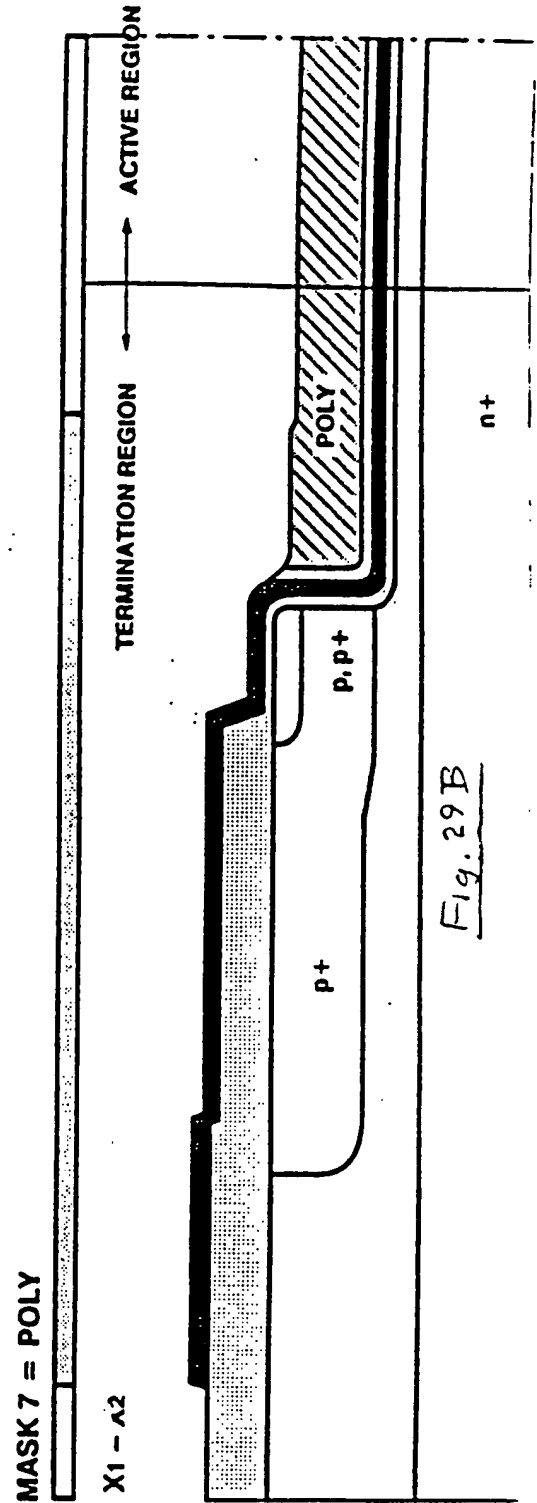


Fig. 29B

rec'd & understood
read and understood

QKWA August 10, 1988
Raulofh Del August 11, 1988

7-MASK TDMOS - PROCESSING BLOCK 9

→ OXIDATION → BPSG DEPOSITION & FLOW → MASK 8 = CONTACT → BPSG REFLOW →

MASK 8 = CONTACT

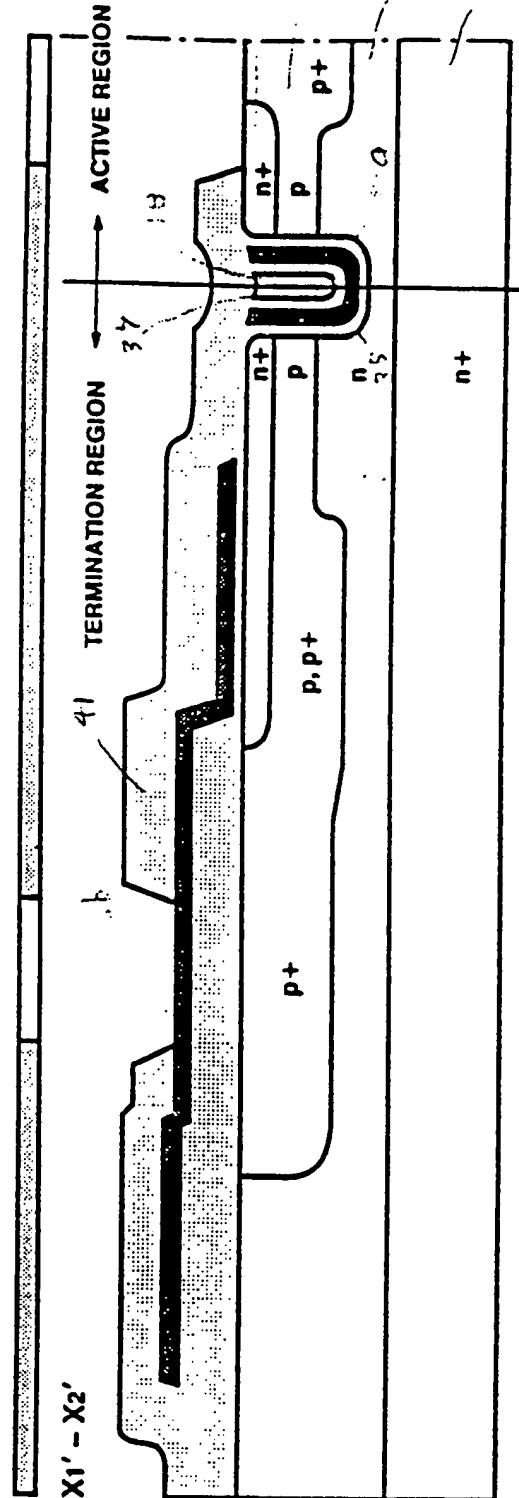
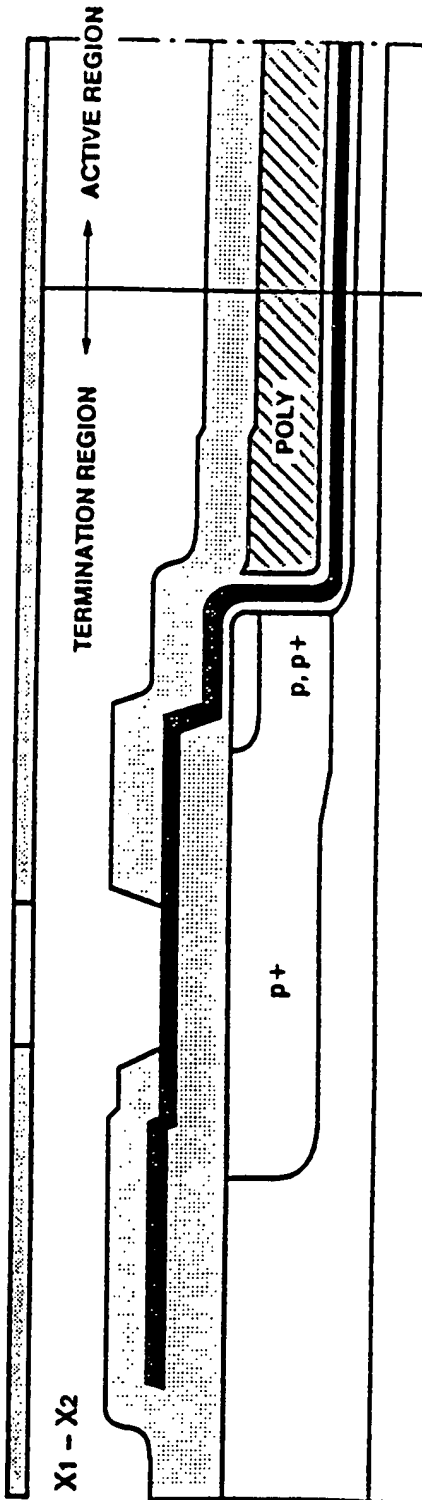


Fig. 30 A

MASK 8 = CONTACT



read & understood Q&W August 10, 1988
read and understood Randolph D. del August 11, 1988

7-MASK TDMOS - PROCESSING BLOCK 10

ALUMINUM DEPOSITION → MASK 8 = METAL → METAL ALLOYING → ELECTRICAL CHECK →

MASK 9 = METAL

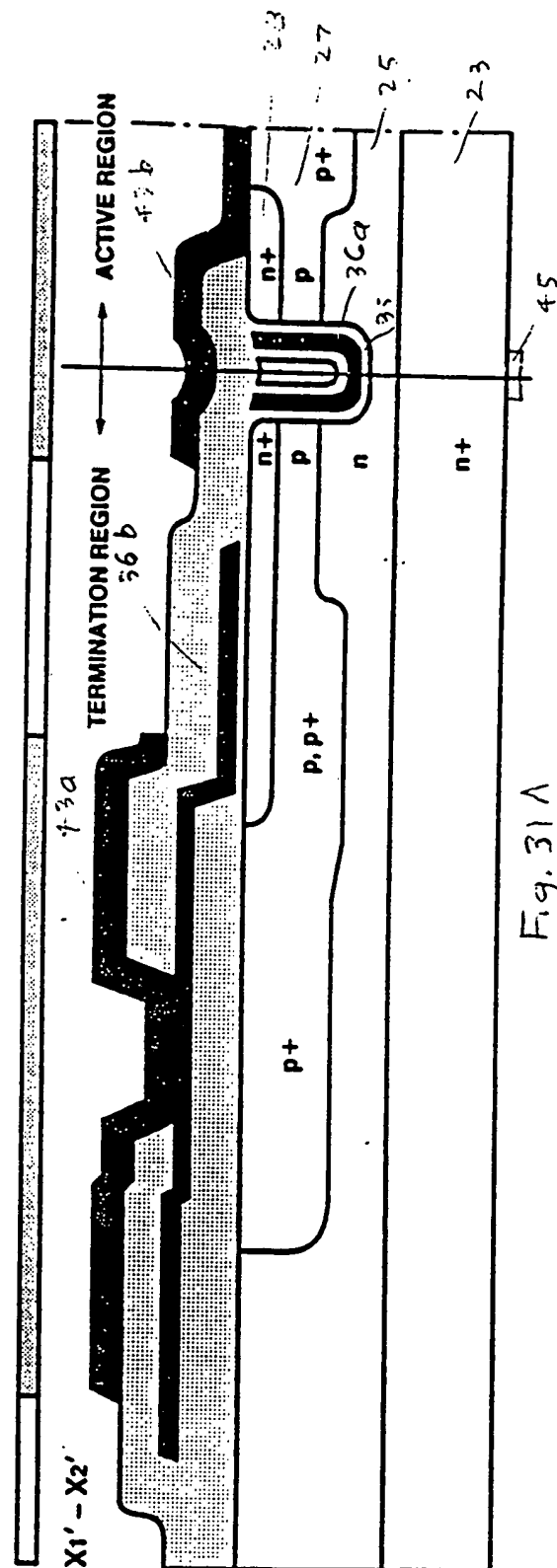
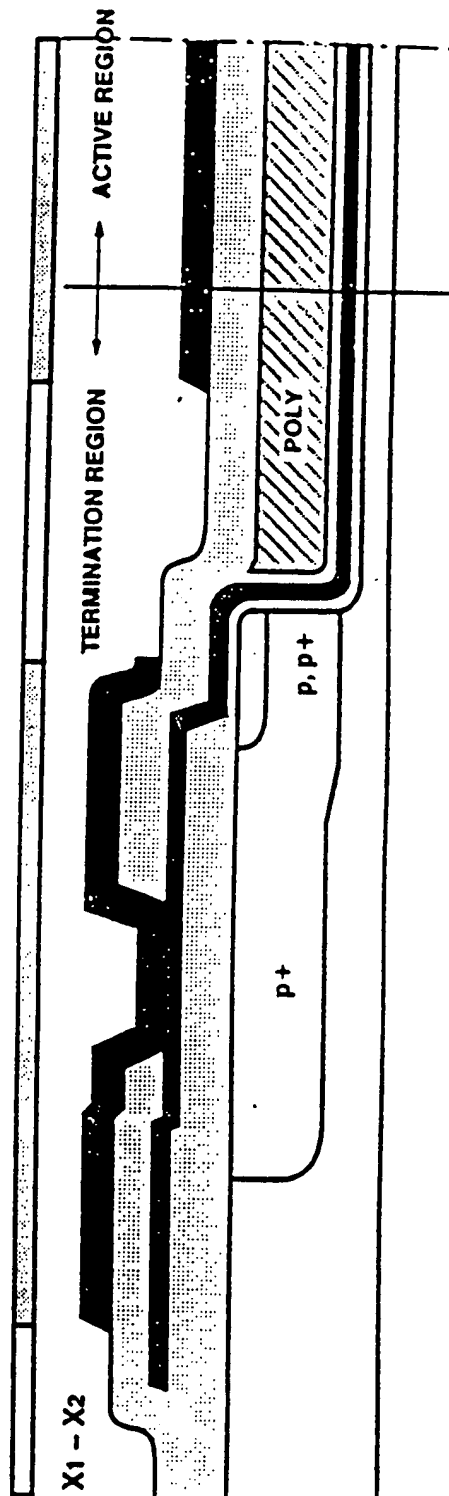


Fig. 31A

MASK 9 = METAL



read & understood Q2 WAA August 10, 1988
 read and understood Randolph D. Lee August 11, 1988



3 October 1988

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SKJERVEN, MORRILL, MacPHERSON
FRIEL

Handwritten initials

11-799



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incorporated

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Mr. Paul J. Winters
Skjerven, Morrill, MacPherson, Franklin & Friel
3600 Pruneridge, Suite 100
Santa Clara, California 95051

Reference: Disclosure of Invention for TRENCHED DMOS POWER TRANSISTORS WITH
OPTIMIZED DEEP-BODY PROFILE AND THREE-DIMENSIONAL GEOMETRY
Inventors: Constantin Bulucea and Rebecca Rossen

Dear Paul:

Please prepare a patent application for this invention for filing in the
United States.

You will note that Constantin Bulucea has not specified his citizenship on
the Invention Disclosure Form, but has shown his U.S. Resident Alien Number. He
was born in Romania, but he says he is no longer Romanian.

Your files M-300, M-300/1, M-300/2, and M-584 may relate to this invention.

Very truly yours,

Siliconix incorporated

Handwritten signature of Lorimer K. Hill

Lorimer K. Hill
Patent Coordinator

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Enclosure:

Disclosure of Invention, dtd 11Aug88, 41 pp.

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